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MINING AND MILLING METHODS AND COSTS AT THE YELLOW PINE MINE, STIBNITE, IDAHO

BY

JOHN D. BRADLEY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MINING AND MILLING METHODS AND COSTS AT THE YELLOW PINE MINE, STIBNITE, IDAHO[1/]

By John D. Bradley[2/]

MINING METHODS AND COSTS

Introduction and History

Stibnite is 76 miles east of Cascade, Idaho, which is 78 miles due north of Boise. The altitude at Stibnite is 6,500 feet, and between Cascade and Stibnite the Forest Service road crosses two summits - Big Creek at 6,800 feet and Warm Lake at 7,300 feet.

The ownership of most of the Meadow Creek group of 190 claims, which is optioned by the Bradley Mining Co from the United Mercury Mines Co , may be traced back from their consolidation by the United Mercury Co. through ownership by prospectors and small promotional companies to the discovery of the Thunder Mountain district in 1900 by the Caswell brothers.

From 1932 when the Yellow Pine Co., which in 1938 was taken over by the Bradley Mining Co., began operations to January 1, 1941, 492,977 tons of ore assaying $5.93 per ton in gold was milled with an average net smelter return for the gold, silver, and antimony of $4.17 per ton. During this 9-year period 68,364 ounces of gold, 213,569 ounces of silver, and 7,875,878 pounds of antimony were recovered from the concentrates.

Most of the production came from the Meadow Creek mine until June 1938 when the mine was temporarily abandoned in favor of larger but lower-grade ore bodies on the Hennessy gold claims about 2-1/2 miles to the north These ore bodies are amenable to surface mining methods; thus, in spite of the fact the ore is lower grade than that from the Meadow Creek mine, the change resulted in a distinct economic advantage, principally owing to the large difference between surface and underground mining costs

At present the property is in a stage of expansion and, in addition, is being developed and equipped to produce tungsten; therefore, the writer discusses the broader aspects of the operation rather than details that undoubtedly will be revised as expansion and alteration continue.

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Geology

The ore bodies now being worked on the Hennessy claims are at the junction of the North and South Meadow Creek fault and the Sugar Creek fault which bears slightly east of north, and they lie in the wedge-shaped area formed by the intersecting faults. From the intersection of the faults the ore zone is known to extend between the faults to a point 900 feet away, where the fault divergence is 600 feet. Little is known as to the further extent of the wedge, but it is believed that the ore bodies continue along the individual faults. This is known to be true of the northeast-bearing zone, as about 400 feet northeast of the suggested northern limits of the wedge an area is being mined 300 feet along the vein where the ore body is 180 feet wide. Branches appear to extend however, from this ore body across to the other fault zone.

The ore body is primarily pyrite and arsenopyrite disseminated through more or less altered granodiorite-aplite country rock. Apparently both of these sulfide minerals are gold-bearing. Stibnite occurs on the west side of the ore zone disseminated through the ore and in high-grade stringers. The two minerals are associated on the west side, but the east side, to which present operations are confined, contains virtually no antimony. Donald E. White, of the Geological Survey, has stated that the deposition of antimony in the neighborhood of present surface operations has been prevented by an andesite dike through which the antimony-bearing solutions were unable to penetrate; the writer concurs in this explanation.

Methods of Prospecting and Estimation of Tonnage

The large Hennessy ore bodies had been thought to exist for several years before their actual development; however, their size, grade, and adaptability to cheap mining were not fully realized. Diamond drilling from two short tunnels on the east and west sides of the ore zone in the latter part of 1937 suggested the importance of these ore bodies. Therefore, in 1938 a large cut about 100 feet wide was begun on the west side of the zone which was called the West Quarry. Production from this area was sufficient to replace that from the Meadow Creek mine by the middle of 1938, so that in June of that year underground production was discontinued.

During operation of the West Quarry the east side was prospected by diamond drilling. This drilling, both from the surface and the original prospecting tunnel run into the ore body several years previously, indicated that the east side of the ore zone would be more profitable than the west owing to higher gold values. Therefore, a crosscut tunnel was driven about 200 feet on the east lode to confirm the results of drilling. Further confirmation was obtained by 400 feet of drifting before stripping of the zone was commenced

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Diamond drilling proved to be a very accurate method of prospecting, consequently ore reserves were estimated on drilling results.

In 1939 the Bureau of Mines began an extensive diamond-drilling program as a strategic minerals project, on the property, which has been most valuable in outlining the antimony-gold ore zones. In addition to the antimony-gold ore thus discovered, the Bureau has exposed some very valuable tungsten ore bodies. In June 1941 drilling for tungsten was proceeding at a rapid pace

Mining Methods

In general, operations consist of drilling with wagon drills, loading the broken ore with a power shovel, and hauling the ore to the mill in trucks.

Bench drilling is done with two wagon drills. One is a Gardner-Denver D-99 and the other is an Ingersoll-Rand. Both the horizontal and vertical holes are drilled dry. Normally the horizontal holes are drilled 18 to 24 feet deep and the vertical holes 24 feet deep; the holes are spaced 5 to 10 feet apart Round, 1-1/4-inch steel with Timken detachable bits is employed. The 24-foot holes are finished with a 2-inch bit.

Down holes are loaded with du Pont "Red Cross" No. 4 free-running explosive in bags and flat holes with du Pont "Gelex" No. 2 in cartridges. Individual springing of the holes is practiced to some extent, and final charges range from 25 to 70 pounds of explosive. The bench holes are blasted electrically. Large boulders are block-holed in the quarry with Ingersoll-Rand S-49 jackhammers using 1-inch hexagonal steel and forged bits. Thirty-percent du Pont special gelatin, caps, and fuse are employed in secondary blasting. In the primary breaking, about 3 tons of ore is broken per pound of explosive.

A Bucyrus-Erie 20-B, 3/4-yard shovel with D-6600 caterpillar engine loads the ore trucks. There are six ore trucks; each is powered with a Cummings HB-6 Diesel engine. Four trucks have the Timken 352 dual worm-drive rear end, one has the Timken 354 dual double-reduction rear end, and one has a double-reduction rear end chain connected to two axles

The surface soil and oxidized ore were stripped with two D-7 caterpillar tractors equipped with Le Tourneau angledozers. Last summer a T-18 International tractor with angledozer was added to speed stripping. There was very little surface soil to be stripped, but the oxidized ore extended to a depth of 20 feet. Waste over flat-lying areas and in the creek bottom is dug by a 5/8-yard Northwest shovel powered with a Wisconsin gasoline engine, which loads two smaller dump trucks.

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Labor, power, and supplies used in mining 12,208 tons

	Man-hour per ton
Labor:	
Breaking ore	0.044
Plugging boulders	.005
Breaking waste	.008
Stripping	.062
Shovel loading	.018
Ore haul	.084
Waste haul	.013
General	.165
Supervision	.041
Total labor at pit, man-shifts	670.6
Labor, percent of total cost	42.1
Average tons per man-shift	18.2

	Pounds	Pound per ton of ore	Tons of ore per pound of powder
Power and supplies:			
Explosives:			
Ore	6,000	0.49	2.03
Waste	2,225	--	--
Plugging boulders	250	--	--
Total	8,475	0.69	1.44

	Horsepower
Power:	
Air compressor	100
3/4-yd. shovel	65
5/8-yd. shovel	50

Mining costs per ton, 1940

Surface mining and stripping	$0.400
Ore hauling and loading	.218
Waste hauling	.019
Total	$0.637

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Itemized cost

Labor	$0.294
Explosives	.085
Diesel fuel	.054
Greases	.007
Lubricating oils	.012
Tires	.028
Miscellaneous	.157
	$0.637

Total costs per ton, 1940

Mining	$0.400
Ore hauling and loading	.218
Waste hauling and loading	.019
Milling	.785
Superintendence and general expense	.125
Camp maintenance	.073
Road maintenance	.031
Concentrate hauling and loading	.194
Insurance	.039
Taxes	.064
Miscellaneous	.050
	$2.00

MILLING METHODS AND COSTS

Introduction

The Yellow Pine concentrator of the Bradley Mining Co. is situated at Stibnite about 2-1/2 miles south of the surface mining operations.

The crushing division comprises three units: A 24- by 36-inch Blake-type jaw crusher, a No. 5 Gates gyratory crusher, and a 3-foot Symons cone crusher.

The grinding division contains two primary Hardinge ball mills - 8- by 3-foot and 8- by 4-foot; each mill is in closed circuit with a Dorr duplex 6- by 25-foot classifier.

The flotation department consists of 8 Denver Sub-A, 43- by 50-inch flotation machines used as roughers, 4 D. S. Kraut cells used as cleaners, and 3 Pan-American 4- by 4- by 4-1/2-foot cells that serve as scavengers. Cleaner concentrates are thickened in an 8- by 20-foot Hardinge thickener and filtered in a 5-foot 4-inch by 6-foot Oliver filter. The present capacity of the plant is 14,000 tons per month.

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Mill water is obtained from the reservoir formed by a dam on the South Fork of Meadow Creek. Water for power is obtained from Meadow Creek and its South Fork and from the East Fork of the South Fork of the Salmon River. There are three hydroelectric plants capable of producing 850 horsepower at high water and four Diesel electric sets with a rated capacity of 400 horsepower at an altitude of 6,500 feet.

Ore Treated

The present heads from the east pit average about $4.75 in gold and about 1/4 ounce of silver a ton. Two types of ore are found at the junction of the Meadow Creek and Sugar Creek faults. One is gold-bearing pyrite and arsenopyrite disseminated through the more or less altered granodiorite-aplite country rock. The other is stibnite, which is disseminated through the gold ore but is localized in the western part of the vein.

History of Concentrator Operations

The entire flotation process was developed in the Berkeley Laboratory, Berkeley, Calif., before operation of the mill.

The original flow sheet comprised grinding to approximately minus-100-mesh and making an antimony and a gold flotation product. The following reagents were used in the flotation of stibnite:

	Pounds per ton
Copper sulfate	1.21
Soda ash	.03
Caustic soda	1.37
Chlorine	.82
Cresylic acid	.30

Flotation resulted in a stibnite concentrate containing:

Gold	oz. per ton	0.77
Silver	do.	10.51
Antimony	percent	48.60

The reagents for the production of gold-iron concentrate comprised:

	Pound per ton
Xanthate	0.006
Pine oil	.056
No. 301	.170

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The gold concentrate for the first year averaged:

Gold	ounces	2.75
Silver	do.	3.37
Antimony	percent	4.14

The final tailings from the operations contained 0.05 ounce of gold, 0.09 ounce of silver, and 20 percent antimony. The foregoing represents the starting period.

By the end of the year, great improvement had taken place, and results for January 1933 were as follows:

	Gold, ounces	Antimony, percent
Heads	0.273	1.85
Antimony concentrate	.468	54.85
Gold concentrate	3.00	3.68
Tails	.047	.15

The reagent cost and distribution remained substantially the same, the tailings were still high, and the antimony content of the gold concentrates was so high as to preclude cyanide extraction.

At the inception of the Yellow Pine enterprise, market as well as technical conditions made necessary the production of stibnite concentrate separate from the arsenopyrite-pyrite-gold concentrate. Laboratory work indicated that production of a 60-percent stibnite concentrate with virtually all the silver of the ore and about 0.5 ounce of gold would be practical and would permit production of a gold concentrate so low in antimony as to make possible roasting and cyaniding the gold.

Production of such an antimony concentrate proved possible, and operation proceeded upon this basis. Production of a gold concentrate also proved practicable, but the recovery of gold therefrom by cyanidation failed. This failure was attributed to the presence of more antimony than had been predicted.

Marketing of stibnite concentrate also proved difficult as at that time there was no antimony-smelting plant in the United States, and foreign buyers failed to offer satisfactory terms considering the content of nearly 30 ounces of silver and as high as 0.75 ounce of gold. The presence of about 1 percent arsenic also was unfavorable.

As most smelting companies penalized the antimony and arsenic going into the lead and copper plants, the market for concentrates of both classes proved to be restricted. Fortunately the United States Smelting Co. plant at

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Midvale was using the Betts process (electrolytic) for refining base bullion, and that required a bullion containing at least 1 percent antimony. Contracts were entered into with the plant for both types of concentrates. Later it was possible to make and sell to the same buyers a bulk concentrate containing all the recoverable gold and antimony.

Present Method of Concentration

The ore trucks dump onto a flat storage area and into a small 25-ton pocket ahead of the jaw crusher. A small bin is used because in the winter the ore would freeze in a larger pocket. The crusher takes the ore out of the pocket as rapidly as the trucks dump it. If there is a hang-up in the crushing plant, the trucks dump onto the flat storage space on a level with the pocket, and a D-2 caterpillar feeds the ore to the bin when the crushing plant again resumes operation.

There is another reason for the use of the flat storage area and small bin rather than a large storage bin. Future plans call for crushing the recently discovered scheelite ore in the same crushing plant. The scheelite ore may be piled on the surface near the bin until it is convenient for the crushing plant to accept this ore at which time it will pass through the plant into the mill bin at the head of the tungsten circuit.

A further reason for such an arrangement is the future and separate treatment of semioxidized ore. This ore will be floated and the flotation tails cyanided.

The present crushing plant went into service in April 1941. Figure 1 is a flow sheet of the mill as of January 1, 1941.

Breaking. - The size of the ore delivered to the mill is governed by what will pass through the 3/4-yard shovel bucket that loads the trucks for delivery to the mill. A 3-inch grizzly ahead of the primary 2- by 3-foot breaker makes about a 4-inch product. This crusher is driven by a 75-horsepower Westinghouse motor by means of a flat belt. About 30 percent of the feed passes through the grizzly.

The secondary crusher is a No. 5 Gates Allis-Chalmers gyratory crusher. Ahead of it is a 2- by 4-inch slotted vibrating screen. Only one-third of the ore passes through the gyratory which crushes to minus 1-1/2-inch. The gyratory is driven by a 50-horsepower General Electric motor with a flat belt.

The final crusher is a 3-foot Symons cone crusher that reduces the feed to minus 1/2-inch. Ahead of the Symons is a Plate-O vibrating screen with

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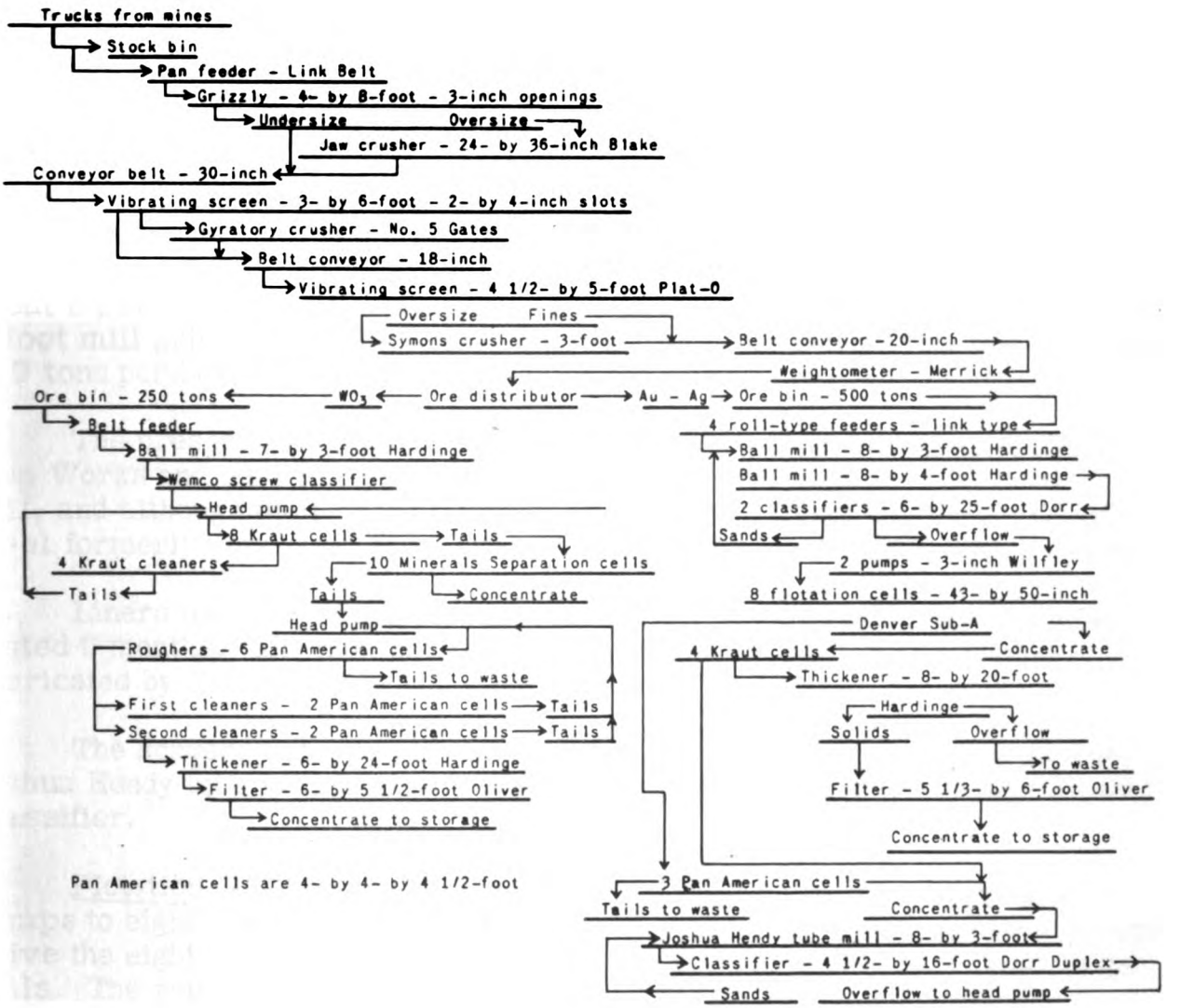

Figure 1.- Flow sheet, Yellow Pine mill, January 1, 1941.

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3/4- by 3-inch openings. Approximately 50 percent of the feed passes through the Symons crusher. The Symons is driven by a 60-horsepower General Electric motor with a flat belt.

The 20-inch conveyor belt from the Symons crusher passes over a Merrick weightometer to the mill bins, where a link-belt distributor discharges the ore into the bins above the ball mills. The capacity of the crushing plant is about 80 tons an hour.

Grinding. - Each of the two 8-foot Hardinge mills is in closed circuit with a 6- by 25- foot Dorr classifier. The mills make about 20 revolutions per minute. The 8- by 4-foot mill is powered by a 200-horsepower motor through a Farrel gear-reduction unit. The 8- by 3-foot mill is powered by a 150-horsepower motor through Farrel gears. The ratio of the circulating load is about 3 : 1. The classifier overflow is 25 percent plus-100-mesh. The 8- by 4-foot mill grinds 11 tons an hour, whereas the 8- by 3-foot mill has an output of 9 tons per hour. About 4.25 pounds of balls are consumed per ton of ore.

The present 3-1/2-inch balls were purchased from the Spokane Union Iron Works and cost $55 per ton at the mine. These balls are rolled steel rail, and although their rate of consumption is higher than that of the forged steel formerly purchased from Oakland, Calif., the low price favors their use.

Liners have also been purchased from the Spokane area but have only lasted 6 months. The next batch of liners will be the supermolychrome fabricated by Eimco Co. in Salt Lake City.

The scavenger froth and cleaner tails are reground in an 8- by 3-foot Joshua Hendy tube mill in closed circuit with a 4-1/2- by 16-foot Dorr Duplex classifier.

Flotation. - The classifier overflow is pumped by two 3-inch Wilfley pumps to eight 43- by 50-inch Denver Sub-A cells; four 10-horsepower motors drive the eight cells. The rougher concentrate is cleaned in four D. S. Kraut cells. The rougher tails are scavenged in three 4- by 4- by 4-1/2-foot Pan-American cells.

Dewatering and filtering. - The cleaner concentrate is dewatered in an 8- by 20-foot Hardinge thickener, and the underflow is filtered in a 5-foot 4-inch by 6-foot Oliver filter. The concentrate is stored in a shed, whence it is loaded onto trucks by a scraper pulling the concentrate over trap doors in the floor of the loading platform.

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The concentrate is weighed in wheelbarrow lots on a platform scale to keep an accurate check on the production, as it is late in the summer of every year before a final check can be obtained with the smelter on the winter production.

The concentrate loses very little of its 10-percent moisture even though it may be stored in the concentrate shed for 6 months because it freezes during the winter months.

Diesel trucks of 15-tons capacity haul the concentrates in bulk to the railroad at Cascade, 76 miles distant. The cost of haulage ranges from $3 to $4 per ton, depending on the condition of the roads.

After all deductions the concentrate averages about $80 per ton. The railroad freight charge from Cascade to the United States Smelting, Refining & Mining Co. smelter at Midvale, Utah, averages about $6.00 per ton. The concentrates are shipped from Cascade in paper-lined boxcars.

Disposal of Tailings. - Tailings run by gravity from the mill to the tailing pond where they are allowed to settle behind a large dike from which the water escapes through the usual sump-box arrangement. The overflow into the sump box is cloudy, as the slimes are extremely slow in settling.

Owing to the necessity for keeping the airport in good condition the tails are run directly into the creek during the winter months, as movement of the tailings under the snow-covered airport would be extremely dangerous.

Concentrator Recovery. - In 1940 mill recovery averaged 70 percent, whereas economic recovery was only 61 percent. The average mill head for this year was $4.94, and returns from the smelter averaged $2.71 per ton of ore milled. The average ratio of concentration for 1940 was 29 : 1.

An average analysis of the concentrate produced during 1940 from the eastern part of the vein follows:

Moisture	percent	10
Au	ounces	3
Ag	do.	3 1/2
Cu	percent	.2
Pb		-
Fe	percent	26.5
Insoluble	do.	33
S	do.	28
Zn		Tr.
Sb	percent	.9
As	do.	8

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A typical flotation-plant operation sheet illustrates the results for May 1941:

Flotation plant operation, May 1941

Product	Tons	Percent by weight	Value of Au per ton	Total value of Au	Distribution
Heads	12,208.50	100.00	$ 5.05	$61,606.77	100.00
Concentrate	537.86	4.41	83.53	44,926.56	72.93
Tails	11,670.64	95.59	1.43	16,680.21	27.07

Smelter settlement estimation

Pay for Au - 2.387 oz. at $32.8183	$78.34
Pay for Ag - 2.80 oz. - 0.5 oz. = 2.30 oz. at $0.70625	1.62
	$79.96
Less freight and treatment	11.73
Net smelter proceeds per ton of concentrate	$68.23
Net smelter proceeds	$36,698.19
Net smelter proceeds per ton of mill feed	3.01

It has been determined that by cyaniding the tails a large part of the loss can be reduced. Six large steel leaching tanks were purchased last winter and would have been installed this spring had not the scheelite discovery demanded immediate additional hydroelectric-power capacity and increased grinding and flotation capacity. This cyanide program will be completed as soon as possible. The values in the tails average about $1.50 per ton and are divided about equally between the sands and slimes. Owing to the increased cost and operating expense for agitating over leaching equipment it is planned to classify the tails, leach the sands, and agitate the thickened slimes.

Summary of costs

The milling costs for 1940 averaged 78.5 cents per ton; the following items comprise this total:

	Cents
Labor	27.40
Balls	13.23
Liners and bolts	7.48
Reagents	8.24
Miscellaneous	22.15
	78.50

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The following table summarizes, on a per-ton basis, the average milling costs, total operating costs, tons milled, value of concentrates, net smelter returns, and economic recovery from the time operations were begun until January 1, 1941.

Summary cost data

Year	Heads	Net smelter returns	Economic recovery, percent	Milling labor	Total milling	Total operating costs	Tons milled
1932	$5.27	$3.05	57.9	$0.59	$1.284	$5.89	34,366
1933	6.76	5.39	79.7	.295	.913	4.33	45,710
1934	8.01	6.29	78.5	.262	.886	4.84	54,000
1935	7.35	5.10	69.4	.277	.867	4.77	50,965
1936	7.26	5.89	81.1	.318	.967	5.11	43,355
1937	5.52	5.40	97.8	.341	.984	5.18	40,330
1938	4.29	3.36	78.3	.315	.937	3.88	35,880
1939	5.06	3.18	62.9	.324	.864	2.90	56,074
1940	4.94	2.71	54.9	.274	.785	2.00	132,297

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